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6.0 MAJOR AUXILIARY SYSTEMS

Learning Objectives:

1. State the purposes, and describe the operation, of each of the major auxiliary systems discussed in this chapter:

    a. Residual heat removal system (RHRS),
    b. Chemical and volume control system (CVCS),
    c. Component cooling water system (CCWS),
    d. Essential service water system (ESWS), and
    e. Spent fuel pit cooling and purification system (SFPCS).

2. Describe the major differences between the US-APWR auxiliary systems and those of currently operating PWRs.

6.1 Residual Heat Removal System

The residual heat removal system transfers heat from the reactor coolant system (RCS) to the essential service water system (via the component cooling water system) to reduce the temperature of the reactor coolant during normal plant shutdown and cooldown conditions. The RHRS is also used to transfer refueling water between the refueling cavity and the refueling water storage pit (RWSP) at the beginning and end of refueling operations.

6.1.1 Design Bases

The RHRS is designed to cool the reactor by removing fission product decay heat and other residual heat from the reactor core and the RCS after the initial phase (primary-to-secondary heat transfer) of the normal plant shutdown and cooldown. The RHRS removes heat at a rate that assures that the acceptable fuel design limits and the design condition of the reactor coolant pressure boundary are not exceeded.

The RHRS has four independent subsystems (trains) available for heat removal. Any two of the four subsystems have a 100% capability for safe shutdown.

The containment spray (CS)/RHR pump and RHRS motor-operated valves receive electrical power from safety buses, so that the RHRS safety functions are maintained during a loss of offsite power (LOOP). Each RHRS train's equipment is powered from a separate electrical train, so that the RHRS safety functions are maintained during the failure of a single electrical train.

Assuming that four trains of CS/RHR heat exchangers and CS/RHR pumps are in service and that essential service water is supplied to the component cooling water heat exchangers at 95°F, the RHRS is designed to provide the capability of reducing the reactor coolant temperature during a normal shutdown as follows:

- To 140°F within 24 hours after reactor shutdown,
- To 130°F within 45 hours after reactor shutdown, and

- To 120°F within 90 hours after reactor shutdown.

Assuming that two trains of CS/RHR heat exchangers and CS/RHR pumps are in service (assuming a single failure in one train and a second train being out of service for preventive maintenance or testing or due to a postulated accident) and that essential service water is supplied to the component cooling water heat exchangers at 95°F, the RHRS is capable of reducing the reactor coolant temperature from 350°F to 200°F within 36 hours of the reactor shutdown.

The RHRS is designed to be isolated from the RCS during normal operation. The RHRS is provided with isolation valves in each suction line with interlocks to prevent them from being opened with RCS pressure above the interlock setpoint.

The RHRS is designed to provide a portion of the RCS flow to the CVCS during normal plant startup operations to control RCS pressure.

The RHRS is designed to transfer borated water from the refueling water storage pit (RWSP) to the refueling cavity at the beginning of a refueling operation. The refueling operation is initiated at a temperature not greater than 140°F. After refueling, the refueling cavity is drained by pumping or by gravity draining the water back to the RWSP.

The RHRS is designed to provide cooling for the in-containment RWSP during normal plant operations when required. The system is manually initiated by the operator. The RHRS limits the RWSP water temperature to a value not greater than 120°F during normal operation.

The RHRS is designed and equipped with pressure relief valves to prevent RHRS overpressurization and low temperature overpressurization of RCS components caused by transients, losses of equipment, and possible operator errors during plant startups, shutdowns, and cold shutdown decay heat removal.

The RHRS is designed to be operated during mid-loop or draindown operation to allow maintenance or inspection of the reactor vessel head, steam generators, and reactor coolant pump seals.

The RHRS is designed to prevent an interfacing system loss-of-coolant accident (LOCA) with two motor-operated isolation valves in series in each pump suction line with power lockout capability. In the event that both of these valves are opened, the RHRS is designed to withstand high pressure and to discharge the reactor coolant inventory to the in-containment RWSP.

The RHRS is designed for protection against missiles, the dynamic effects associated with the postulated rupture of piping and pipe whipping, the discharging of fluids inside and outside the containment, fires, LOCA loads, and seismic effects.

The suction side of the RHRS piping up to the second isolation valve is equipment class 1. The rest of RHRS is designed as equipment class 2, except that the shell sides of CS/RHR heat exchangers are equipment class 3.

6.1.2 System Description

As shown in Figures 6-1 and 6-2, the RHRS consists of four independent subsystems, each of which receives electrical power from one of four separate safety buses. Each subsystem includes one CS/RHR pump, one CS/RHR heat exchanger, and associated piping, valves, and instrumentation necessary for operational control. Table 6-1 provides the important system equipment design parameters. The CS/RHR heat exchangers and the CS/RHR pumps provide functions for both the containment spray system (CSS) and the RHRS.

The RHRS is placed in operation when the pressure and temperature of the RCS are approximately 400 psig and 350°F, respectively.

The inlet lines to the RHRS are connected to the hot legs of the four reactor coolant loops, while the return lines are connected to the cold legs of the loops. With the RCS at high pressure, the RHRS suction lines are isolated from the RCS by two normally closed motor-operated valves, with power lockout capability, that are connected in series and located inside the containment. Each discharge line is isolated from the RCS by two check valves located inside the containment and by a normally closed motor-operated valve.

During RHRS operation, each CS/RHR pump takes suction from one of the RCS hot legs via a separate suction line. The pumps then discharge the reactor coolant through the CS/RHR heat exchangers, which transfer heat from the hot reactor coolant to the component cooling water (CCW) circulating through the shell sides of the CS/RHR heat exchangers. The cooled reactor coolant is then returned to the RCS cold legs.

CS/RHR pumps transfer borated water from the RWSP to the refueling cavity at the beginning of the refueling operation, and after refueling transfer the water back to the RWSP until the water level is lowered to the elevation of the reactor vessel flange.

Coincident with operation of the RHRS, a portion of the reactor coolant flow from two trains (A and D) may be diverted from downstream of the CS/RHR heat exchangers to the CVCS low pressure isolation letdown line for cleanup and/or pressure control. By regulating the diverted flow rate and the charging flow, the RCS pressure may be controlled.

The RCS cooldown rate is manually controlled by regulating the reactor coolant flow through the tube sides of the CS/RHR heat exchangers. The flow control valves in the bypass lines around two of the four CS/RHR heat exchangers (A and D) automatically maintain a constant return flow to the RCS. Instrumentation is provided to monitor system pressure, temperature, and total flow.

When the RHRS is in operation, the system’s water chemistry is the same as that of the reactor coolant. Provisions are made for the process sampling system to extract samples from downstream of two CS/RHR heat exchangers (B and C). A local sampling point is also provided in each RHR train between the pump and the heat exchanger.

Pump protection is provided by a minimum flow line, with an open valve and an orifice, running from the downstream side of each CS/RHR heat exchanger to the associated CS/RHR pump suction. This line is sized to provide sufficient pump flow when the CS/RHR pump is at shutoff head.

The RHRS suction isolation valves in each inlet line from the RCS are interlocked to prevent them from being opened when the RCS pressure is greater than approximately 400 psig. The valves have a control room alarm which alerts the operators if one or both of the valves is not fully closed and the RCS pressure exceeds 400 psig.

6.1.3 Component Descriptions

All RHRS components in contact with borated water are made of austenitic stainless steel. However, the shells of the CS/RHR heat exchangers are made of carbon steel. The materials used to fabricate RHRS components are in compliance with ASME Code Section III material requirements.

6.1.3.1 CS/RHR Pumps

The CS/RHR pumps are horizontal, motor-operated, centrifugal pumps with mechanical seals. A single unit is provided in each of the four trains. The pumps are installed in separate shielded rooms so that one of the four pumps may be maintained while the others are in operation.

The pumps are sized to deliver reactor coolant flow through the CS/RHR heat exchangers to meet the plant cooldown requirements. The design head of the CS/RHR pumps is 410 feet. During normal plant shutdowns, mid-loop operation, and safe shutdowns, the RHR pumps are aligned to take suction from the RCS hot legs and to discharge the reactor coolant through the CS/RHR heat exchangers to the cold legs. The use of a separate pump in each RHR train ensures that cooling capacity is only partially lost should one pump become inoperative.

The CS/RHR pumps are used for transferring the refueling water from the RWSP to the refueling cavity and may be used for returning the refueling water from the refueling cavity to the RWSP.

The CS/RHR pumps are protected from overheating and loss of suction flow through pump shutoff by means of minimum flow bypass lines that ensure flow to the pump suctions. The minimum flow lines are used for pump testing during normal operations.

6.1.3.2 CS/RHR Heat Exchangers

The CS/RHR heat exchangers are provided to cool the reactor coolant during RHRS operation. The CS/RHR heat exchangers remove residual heat during normal shutdowns, during shutdowns following the loss of external power sources, and during safe shutdowns. The CS/RHR heat exchangers are of the shell-and-U-tube type; they can accommodate the difference in the rates of thermal expansion between the tubes and the shells. The tubes are welded to the tube sheet to prevent leakage of the reactor coolant. A single unit is provided in each of the four trains. The units are installed in separate rooms so that one of the four heat exchangers may be repaired while the others are in operation.

The reactor coolant discharged from each CS/RHR pump is circulated through the tube side of the associated CS/RHR heat exchanger, where cooling is provided by CCW circulating through the shell side.

The CS/RHR heat exchanger design is based on heat loads and temperature differences between reactor coolant and CCW during normal and safe shutdowns.

6.1.3.3 Major Valves

CS/RHR Pump Hot Leg Isolation Valves: Two normally closed motor-operated gate valves, with power lockout capability, are aligned in series in the suction line for each of the four RHRS trains between the high pressure RCS and the low pressure RHRS. These valves isolate the RCS from the low pressure RHRS piping.

These valves comprise part of the reactor coolant pressure boundary. The second valve is a containment isolation valve. The first and the second valves in each train are interlocked so that they cannot be opened when the RCS pressure is above 400 psig, and when the corresponding spray header isolation valves are not closed to prevent spraying reactor coolant through the CSS nozzles. Each set of valves has a control room alarm, which alerts the operators if either valve is not fully closed and the RCS pressure exceeds 400psig.

RHR Discharge Line Containment Isolation Valves: There is one normally closed, motor-operated gate valve installed in each CS/RHR pump discharge line outside of containment. These valves have electrical power removed during normal plant conditions. They are opened by the operator from the main control room (MCR) for cooling of the RWSP contents by the CS/RHR heat exchangers following an accident, during full-flow pump testing, and during normal RHRS operation.

RHR Flow Control Valves: A single motor-operated globe valve with throttling capability is placed in each of the four RHRS return lines. These valves are positioned from the MCR. These valves provide the capability to control the RHRS flow rates during initial system warmups and during safe shutdown operations.

Low Pressure Letdown Line Isolation Valves: A single normally closed air-operated valve is placed in each of the two lines which supply CS/RHR pump discharge to the CVCS letdown line. During normal plant cooldown operations, one of these valves is open to divert a portion of the RCS flow to the CVCS for the purpose of purification and RCS inventory control.

Additionally, during mid-loop operation, these valves are automatically closed, and the CVCS is isolated from the RHRS, on the receipt of an RCS loop low-level signal to prevent the loss of RCS inventory.

CS/RHR Heat Exchanger Outlet Flow Control Valves: There are air-operated butterfly valves in two of the four CS/RHR heat exchanger outlet lines. The modulated open positions of these valves can be manually adjusted from the MCR, and the valves fail in the open position to ensure flowpaths for RHRS and CSS operations. These valves provide the capability to control the flow rates through the heat exchangers by operator action based on the RCS temperature changes during plant cooldowns.

CS/RHR Heat Exchanger Bypass Flow Control Valves: There are air-operated butterfly valves in the CS/RHR heat exchanger bypass lines provided for two of the four heat exchangers. These valves, together with the CS/RHR heat exchanger outlet flow control valves, control the reactor coolant return flows during plant cooldown operations. The throttled positions of the CS/RHR heat exchanger outlet flow control valve are set by the operator. Each bypass flow control valve is then automatically positioned by a flow controller to maintain a constant flow rate in that RHRS train. The valves fail in the closed position.

CS/RHR Pump Full-Flow Test Line Stop Valves: One normally closed motor-operated globe valve with throttling capability is placed in each of the four CS/RHR pump test lines. These lines are located inside the containment and are routed from the pump discharge lines to the RWSP. These valves are manually opened when the pumps are aligned for full-flow tests during plant shutdowns. These valves are also manually opened by the operator from the MCR to align the CS/RHR pumps and heat exchangers to remove heat from the containment for an extended period of time by continuous recirculation of RWSP water once containment spray is no longer required.

CS/RHR Pump Suction Relief Valves: One relief valve is installed in each of the four CS/RHR pump suction lines. These valves protect the CS/RHR piping from overpressurization caused by the most severe overpressure transients during plant startup and normal cooldown operations. These valves provide the containment boundary function since they are connected to the containment boundary piping. Each relief valve has a relief capacity of approximately 1320 gpm at an approximate set pressure of 470 psig.

These valves also provide low-temperature overpressure protection for RCS components when the RHRS is aligned to the RCS for decay heat removal during plant shutdown and startup operations. These valves discharge to the RWSP.

CS/RHR Heat Exchanger Outlet Relief Valves: One pressure relief valve is installed in each of the four CS/RHR heat exchanger discharge lines. These valves are designed to protect the RHR piping from overpressurization due to possible backleakage from the RCS or to thermal expansion of the trapped water when the RHRS is isolated from the RCS. Each relief valve has a flow capacity of approximately 20 gpm at an approximate set pressure of 900 psig. These valves discharge to the RWSP.

6.1.4 System Operation

The RHRS is designed to be fully operable from the control room and the remote shutdown panel for normal operations, except for restoring power to the suction isolation valves prior to RHRS initiation. Manual operations required by the control room operator are opening the suction isolation valves, opening the RHR flow control valves, opening the low pressure letdown line isolation valves, opening the RHR discharge line containment isolation valves, and starting the CS/RHR pumps. During a normal cooldown, time and accessibility are adequate to perform these actions.

6.1.4.1 Plant Startup

Generally, while in the cold shutdown condition, decay heat from the reactor core is removed by the RHRS. The numbers of pumps and heat exchangers in service depend on the prevailing heat load.

At the beginning of a plant startup, at least one CS/RHR pump is operating, and the RHRS is aligned to divert a portion of the RHR flow through a low pressure letdown path to the CVCS for control of RCS pressure. After the reactor coolant pumps are started, the RHRS is operated as necessary for heat removal. Once pressurizer steam bubble formation is complete, the RHRS would be isolated from the RCS.

6.1.4.2 Normal Operation

The CS/RHR pumps are not in service during power generation and hot standby operations. During normal operation the RHRS is not used, and the CSS is in standby. The CS/RHR pumps are normally aligned to take suction from the RWSP. The tubes of the CS/RHR heat exchangers are filled with borated water, and the shells of the heat exchangers are filled with CCW.

6.1.4.3 Plant Shutdown

The initial phase of plant shutdown is accomplished by transferring heat from the RCS to the steam and power conversion system through the SGs. Depressurization is accomplished by spraying reactor coolant into the pressurizer to cool and condense the pressurizer steam bubble.

The second phase of cooldown starts with the RHRS being placed in operation when the reactor coolant temperature and pressure are reduced to approximately 350°F and 400 psig, respectively, approximately four hours after reactor shutdown. Startup of the RHRS includes a warmup period, during which the reactor coolant flow rate is slowly increased through the heat exchangers to protect the piping and components in the RHRS from thermal shock. After the warmup, the rate of heat removal from the reactor coolant is manually controlled by the operator by regulating the coolant flow through the CS/RHR heat exchangers. This is accomplished by modulating the CS/RHR heat exchanger outlet flow control valves in two subsystems. The CS/RHR heat exchanger outlet flow control valves are positioned by the operator, and the CS/RHR heat exchanger bypass flow control valves are automatically positioned to maintain constant flow rates through the associated RHRS trains.

The reactor cooldown rate is limited by the allowable stress limits of the reactor vessel and the SGs and by the operating temperature limits of the CCWS. As the RCS temperature decreases, the reactor coolant flow through the CS/RHR heat exchangers is increased by adjustment of the heat exchanger outlet flow control valves.

When operation of the two RHRS subsystems with bypass flow control cannot maintain the cooldown rate, then the other two subsystems without bypass flow control are sequentially placed in service. Reactor coolant flows at constant flow rates through the CS/RHR heat exchangers of the subsystems without bypass flow. During plant cooling, the pressurizer is fully filled with water, and the RCS pressure may be controlled by regulating the charging flow to the RCS and the low pressure letdown flow to the CVCS.

Should one train's CS/RHR heat exchanger outlet and bypass flow control valves fail simultaneously (e.g., due to a loss of instrument air), then the cooldown rate may increase. In this case, the operator can limit the cooldown rate by throttling the RHR flow control valve of that train.

After the reactor coolant pressure has been reduced sufficiently and the coolant temperature has been lowered to 140°F, the refueling or maintenance operations are initiated.

6.1.4.4 Safe Shutdown

It is expected that the systems normally used for safe shutdown (cooldown to cold shutdown conditions) will be available any time the operator chooses to perform a reactor cooldown. However, to ensure that the plant can be taken to cold shutdown, the safety-grade cold shutdown design enables the RCS to be taken from no-load temperature and pressure to cold conditions using only safety-related systems, with only onsite power available, and assuming the most limiting single failure.

The safety-grade cold shutdown design enables the operator to maintain the plant in hot standby for up to approximately 14 hours. Since it is assumed that the reactor coolant pumps are not available, circulation of the reactor coolant is provided by natural circulation with the reactor core as the heat source and the SGs as the heat sink. Heat removal is accomplished through the main steam relief valves and the emergency feedwater system.

Boration of the RCS is initiated prior to cooling the RCS. The safety injection pumps are used to deliver borated water to the RCS through the safety injection lines. The flowpaths have provisions for flow control. To accommodate this addition to RCS inventory, continuous letdown is discharged via the emergency letdown lines to the RWSP.

The second phase of the cooldown is performed by the RHRS. The cooldown can be performed with as few as two of the four RHRS trains, assuming a failure of one train and a second train out of service for maintenance, in conjunction with the CCWS and ESWS. The cooldown rate of the RCS is manually controlled by the motor-operated RHR flow control valves in the jog-throttle mode.

6.1.4.5 Refueling

Before refueling oerations one or more CS/RHR pumps transfer borated water from the RWSP to the refueling cavity. During this operation, RHRS train(s) are selected for water transport; those trains' CS/RHR pump hot leg isolation valves are closed and their CS/RHR pump RWSP isolation valves are opened. The refueling cavity is prepared for flooding, and the vessel head is removed to its storage pedestal using the containment polar crane. The refueling water is transferred by the CS/RHR pumps into the reactor vessel through the RHR return lines and into the refueling cavity through the open reactor vessel flange. The reactor vessel head is unbolted to begin refueling operations, and the head is lifted as the refueling water level increases. After the water level reaches the normal refueling level, the CS/RHR pumps are stopped, the RWSP isolation valves are closed, the CS/RHR pump hot leg suction isolation valves from the RCS are re-opened, and the pumps are restarted to resume decay heat removal.

During refueling, the RHRS is maintained in service, with the number of pumps and heat exchangers in operation as required for the heat load.

Following refueling, the CS/RHR pumps are used to lower the water level in the refueling cavity to the top of the reactor vessel flange. This is done by pumping water from the RCS through the pump full-flow test lines to the RWSP as the reactor vessel head is lowered into place. The vessel head is then replaced, and the normal RHRS flowpaths are re-established. The refueling cavity can also be drained by gravity to the RWSP without the operation of pumps.

6.1.4.6 Mid-Loop and Draindown Operations

The RHRS is used to provide core cooling when the RCS must be partially drained to allow maintenance or inspection of the reactor head, SGs, or reactor coolant pump seals. Mid-loop operation involves residual heat removal while the RCS water level is lowered to and then maintained near the pipe centerline level of the hot and cold legs. A major concern during mid-loop operations is a further decrease in RCS water level, which can lead to inadvertent air entry into the RHRS and possible loss of CS/RHR pump function.

To minimize the potential for air entry into the RHRS, the RCS water level should be higher than 0.33 ft above the mid-loop level, and an RHR flow of 1550 to 2650 gpm should be supplied. The US-APWR design includes additional features which support reliable mid-loop operation:

- Redundant water level instrumentation: Redundant narrow-range water level instruments and a mid-range level instrument are installed. A temporary mid-loop level sensor that measures the RCS water level with reference to pressure at the reactor vessel head vent line and cross-over leg is also installed to cope with surge line flooding events.

- Interlock for low RCS water level: When the water level of the RCS drops below the mid-loop level, the low pressure letdown lines are isolated automatically to prevent the loss of reactor coolant inventory.

- Water supply from the spent fuel pit: When the water level of RCS drops below the mid-loop level and all CS/RHR pumps cannot be operated because of air intake, the operator can supply water from the spent fuel pit (SFP) to the reactor vessel. Since the RHRS suction lines are connected to the SFP, SFP water can be injected by gravity via the RHRS.

6.2 Chemical and Volume Control System

The chemical and volume control system is a normally operating system providing many auxiliary functions related to the control of reactor coolant volume, chemistry, and radioactivity. During at-power operation a portion of the reactor coolant flow is directed into the CVCS, where it is filtered and demineralized, and then returned to the RCS as charging and seal injection. Chemicals are added for corrosion and reactivity control as necessary. The CVCS performs the following functions:

- Maintains the coolant inventory in the RCS for all normal modes of operation, including startup, full-power operation, and cooldown,

- Provides makeup capability for small RCS leaks,

- Performs purification by removal of fission and activation products in the reactor coolant,

- Regulates the boron concentration in the reactor coolant during normal operation,

- Borates the reactor coolant system for cold shutdown,

- Controls the reactor coolant water chemistry,

- Supplies cool filtered water to the shafts seals and bearings of the reactor coolant pumps (RCPs), and

- Provides pressurizer auxiliary spray water for depressurization of the RCS when none of the RCPs is operating.

6.2.1 Safety-Related Design Bases

The safety-related design bases for the CVCS are as follows:

- Provides a portion of the reactor coolant pressure boundary,

- Provides containment isolation of CVCS lines which pentrate containment,

- Provides isolation capability for the charging line in response to either an ECCS actuation signal or a high pressurizer water level, and

- Provides isolation capability for the reactor coolant boron dilution source to prevent an inadvertent dilution of the reactor coolant.

All other functions provided by the CVCS are not safety related.

6.2.2 System Description

The CVCS consists of two charging pumps, the regenerative heat exchanger, the letdown heat exchanger, the excess letdown heat exchanger, demineralizers, filters, pumps, tanks, and associated valves, piping, and instrumentation. The system diagram is shown in Figure 6-3. The system parameters are provided in Table 6-2.

6.2.2.1 RCS Inventory Control, Reactor Coolant Pump Seal Injection, and Makeup

Reactor coolant is discharged to the CVCS from RCS loop D cross-over piping. During normal operation, this reactor coolant (letdown) is cooled by flowing through the shell side of the regenerative heat exchanger, and then it flows through the letdown orifices, where the reactor coolant pressure is reduced. The coolant then passes through the letdown heat exchanger, where its temperature is further reduced. The reactor coolant pressure is further reduced by a pressure control valve located downstream of the letdown heat exchanger. This valve is provided to maintain the upstream pressure high enough to prevent flashing downstream of the letdown orifices.

Normally, the reactor coolant letdown flows through one mixed-bed demineralizer inlet filter and one mixed-bed demineralizer, then passes through the reactor coolant filter, and then enters the volume control tank (VCT) through the spray nozzle.

The gas space of the VCT is filled with hydrogen. The hydrogen pressure in the VCT is controlled to establish the concentration of hydrogen dissolved in the reactor coolant.

To reduce the amount of radioactive gases dissolved in the reactor coolant, the gas in the VCT gas space can be purged to and processed by the gaseous waste management system (GWMS).

Normal charging is provided by a single charging pump. The charging pump takes suction from the VCT and returns the purified reactor coolant to the RCS. The flow rate of the charging pump discharge is controlled by the flow control valve located in the charging line and the flow control valve located in the reactor coolant pump seal injection line. The charging line flow control valve is controlled by the charging flow rate-control unit, which responds to the following inputs: pressurizer water level signal, charging flow rate signal, and letdown flow rate signal. A portion of the flow is directed to the reactor coolant pumps through a seal water injection filter. The flow to the reactor coolant pumps is controlled by a flow control valve located in the reactor coolant pump seal injection line.

Recirculation flow for charging pump protection branches from the pump discharge, flows through the seal water heat exchanger, and returns to the outlet of the VCT. Most of the charging flow is injected to the RCS loop A cold leg through the tube side of the regenerative heat exchanger. The regenerative heat exchanger performs heat exchange between the charging flow and the letdown flow to raise the charging flow temperature nearly to the temperature in the reactor coolant loop. A branch line from the charging line downstream of the regenerative heat exchanger is routed to the auxiliary pressurizer spray line. The auxiliary pressurizer spray provides a means of cooling and depressurizing the pressurizer near the end of a plant cooldown, when the reactor coolant pumps are not operating.

The remainder of the charging flow is supplied to the RCP shaft No. 1 seals through the seal water injection filter. A portion of the seal water flows along each pump shaft downward into the RCS through the pump shaft bearing labyrinth seal and the thermal barrier. The remainder of the seal water runs along the pump shaft upward through the No.1 seal and exits the pump and discharges to the common No. 1 seal water return line. The combined seal water return from all four RCPs exits the containment vessel, passes through the seal water return strainer and the seal water heat exchanger, and returns to the VCT outlet line.

The excess letdown line from the RCS is provided for the possible malfunction of the normal letdown line. When excess letdown is placed in service, the reactor coolant is directed to the CVCS from the loop A cross-over piping to the tube side of the excess letdown heat exchanger, where it is cooled to about 165°F. The excess letdown flow rate is controlled by the excess letdown flow control valve located downstream of the heat exchanger. The excess letdown flow joins with the RCP seal return and then flows through the seal water heat exchanger to the outlet line of the VCT. The excess letdown flow can also be discharged directly to the reactor coolant drain tank. The excess letdown flowpath is also utilized to supplement the normal letdown flow during the final stage of a plant heatup. This additional letdown capability helps to accommodate the reactor coolant expansion during a heatup.

Surges due to load changes in the RCS are mostly accommodated by the pressurizer; however, the VCT provides the surge capacity for any reactor coolant expansion volume which can not be accommodated by the pressurizer. The letdown flow normally flows into the VCT. When the water level in the VCT reaches the high-level setpoint, the letdown flow is routed to the holdup tank by the VCT inlet three-way valve. When the water level in the VCT reaches the low-level setpoint, the reactor makeup water control system starts to provide makeup. If the reactor makeup water control system cannot supply makeup water at a rate sufficient to prevent a further decrease in the VCT water level, a low-low VCT level alarm is actuated, and the suction of the charging pump is switched from the VCT to the refueling water storage auxiliary tank (RWSAT). The charging pump can also take suction from the spent fuel pit, which serves as a safe-shutdown makeup water source.

6.2.2.2 Purification

Ionic Purification: Two mixed-bed demineralizers are provided in the letdown line to remove ionic fission and corrosion products. One mixed-bed demineralizer is continuously utilized during normal letdown operation; it can be supplemented intermittently or continuously by the cation-bed demineralizer. If the ion exchange capability of the normally operating mixed-bed demineralizer is diminished, the other mixed-bed demineralizer is placed into service.

The cation-bed demineralizer is used for adjusting the pH in the reactor coolant by removing lithium and for removing fission products introduced into the coolant through fuel defects to improve the purification function. The cation-bed demineralizer mainly removes lithium and cesium isotopes.

Reactor coolant filters are provided downstream of the demineralizers to collect particulates and resin fines from the reactor coolant.

A temperature sensor monitors the temperature of the letdown flow downstream of the letdown heat exchanger. If the letdown temperature exceeds the maximum allowable demineralizer resin operating temperature (approximately 140°F), an air-operated three-way valve in the letdown line is automatically repositioned so that the flow bypasses the demineralizers. Temperature indication and a high-temperature alarm are provided at the main control board. On a loss of air, the three-way valve directs flow to the VCT.

Gaseous Purification: Removal of radioactive gases from the coolant is not normally necessary because the gases do not build up to unacceptable levels when fuel defects are within normally anticipated ranges. If radioactive gas removal is required because of many fuel defects, fission gasses are removed from the reactor coolant by purging the gas space of the VCT to the GWMS. A remotely operated vent valve in the GWMS permits continuous removal of gaseous fission products from the VCT.

6.2.2.3 Chemical Shim and Chemical Control

Chemical Shim and Makeup: RCS boron changes are required to compensate for fuel depletion, startups, shutdowns, and refuelings. Adjustment of the coolant boron concentration through the addition of boric acid or primary water is controlled by the reactor makeup control system.

Heavily borated water at a concentration of 7,000 ppm (4 weight percent) boron is stored in the two boric acid tanks. In response to the appropriate reactor makeup control signals, a boric acid transfer pump provides boric acid from the boric acid tanks, a primary makeup water pump provides unborated water, or each pump provides flow to the boric acid blender. From the blender, makeup flow is sent to the suction side of the operating charging pump and/or sprayed into the VCT through the spray nozzle.

The boric acid transfer pumps are also utilized to circulate the boric acid solution in the boric acid tanks.

During long-term dilution, primary makeup water is periodically routed to the VCT letdown inlet. This flow mixes with the hydrogen blanket in the tank to ensure hydrogen entrainment in the water. If alternate dilution is necessary, some primary water flow is routed to the suction side of the charging pump in addition to the volume control tank.

Boric acid can also be removed from the reactor coolant by a deborating demineralizer to compensate for fuel burnup near the end of core life.

pH Control: The chemical agent used for pH control is lithium hydride (LiOH). This chemical is chosen for its compatibility with the materials and water chemistry of a system containing borated water, stainless steel, and zirconium. In addition, lithium-7 is produced in the core region because of neutron absorption by the dissolved boron in the coolant.

A chemical mixing tank is provided to introduce the chemical solution to the suction of the charging pumps. The chemical solution is added into the chemical mixing tank and is then flushed to the suction side of the charging pumps with primary makeup water. To maintain the reactor coolant pH in accordance with plant operating requirements, the Li-7 concentration in the reactor coolant is increased as necessary by feeding LiOH from the chemical mixing tank, and decreased as necessary by directing reactor coolant to the cation-bed demineralizer.

Oxygen Control: The CVCS provides control of the RCS oxygen concentration during plant startup from cold conditions through the addition of hydrazine as an oxygen-scavenging agent. The hydrazine solution is injected into the RCS in the same manner as described above for LiOH. Hydrazine is only used during startups from cold shutdown conditions.

Control and scavenging of oxygen generated by water radiolysis in the core region during normal at-power operation is performed by supplying hydrogen to the reactor coolant. The VCT maintains a sufficient hydrogen pressure; therefore, the equilibrium hydrogen concentration in the reactor coolant is maintained. Hydrogen is supplied to the VCT via the hydrogen manifold, and the required pressure of the gas space in the VCT is maintained by a hydrogen supply pressure control valve.

6.2.2.4 Boron Recycling

The CVCS includes the boron recycle subsystem. A holdup tank receives the reactor coolant discharged from the RCS and other reactor coolant recyclable drains. This discharge is then processed as unborated makeup water and concentrated borated water.

The reactor coolant entering the holdup tank releases dissolved hydrogen and gaseous fission products. These gases mix with the nitrogen cover gas in the tank. Gases displaced by the incoming reactor coolant are routed to the waste gas surge tank through the waste gas compressor. Makeup of the cover gas to the holdup tank is normally done by reusing the gas from the surge tank. If necessary, makeup nitrogen can be supplied through the nitrogen supply manifold.

The boric acid evaporator feed pump transfers water from the holdup tank to the boric acid evaporator by first passing the waste through the boric acid evaporator feed demineralizer, where lithium and radioactive ions are removed.

The boric acid evaporator removes hydrogen, nitrogen, and residual gaseous fission products from the reactor coolant. The coolant is then separated into borated water of approximately 7,000 ppm boron (boric acid) and distilled water. While one batch of boric acid is being processed, the boric acid evaporator continuously receives feed water and discharges distilled water.

The distilled water discharged from the boric acid evaporator is transferred to the primary makeup water tank or released to the liquid waste management system. Meanwhile, the concentration of the boric acid is gradually increased until it reaches 7,000 ppm boron. The boric acid is intermittently sampled to determine whether further processing is necessary. If the sampling results meet the specifications for boric acid to be used for makeup, the operation is terminated and the concentrate is transferred to the boric acid tanks. If the concentrate does not satisfy the specifications after the concentration procedure, it is returned to the holdup tank for reprocessing.

6.2.3 Component Descriptions

CVCS equipment design parameters are listed in Table 6-3. Components which contact reactor coolant are constructed of stainless steel.

6.2.3.1 Pumps

Two multi-stage centrifugal charging pumps, arranged in parallel, supply reactor coolant to the RCS. Normally, one running pump takes suction from the VCT and supplies charging and seal water flows. The other pump is in standby. Each pump provides the full capability for normal makeup.

Two centrifugal boric acid transfer pumps are used to transfer boric acid from the boric acid tanks and to recirculate boric acid tank contents.

Two centrifugal boric acid evaporator feed pumps supply water from the holdup tanks to the boric acid evaporator and recirculate the water in the holdup tanks to mix the tank contents.

6.2.3.2 Heat Exchangers

One regenerative heat exchanger, with charging flow in the tubes and letdown flow in the shell, is provided. Heating the charging flow improves thermal efficiency and reduces thermal stresses on the pipe nozzle connecting the charging line to the RCS. Cooling the letdown flow prevents flashing of the letdown downstream of the letdown orifices.

One horizontal U-tube letdown heat exchanger, with letdown flow in the tubes and component cooling water (CCW) flow in the shell, is provided. The exiting letdown temperature is controlled through adjustment of the CCW flow; the letdown temperature is maintained at the appropriate value for downstream components.

One excess letdown heat exchanger, with letdown flow in the tubes and CCW flow in the shell, is provided. At normal operating conditions, the excess letdown flow is equivalent to the seal injection that enters the RCS through the RCP shaft bearing labyrinth seals.

The seal water heat exchanger cools RCP seal return, excess letdown, and charging pump minimum flow. Those flows are cooled by CCW flow in the heat exchanger shell.

6.2.3.3 Tanks

The VCT receives coolant insurges that are not accommodated by the pressurizer and contains a hydrogen blanket for maintaining the proper hydrogen concentration in the reactor coolant. The tank has two spray nozzles; one is normally in service, and both are used to accommodate high inlet letdown flows.

Two boric acid tanks are provided. The combined capacity of the two tanks provides the total boric acid solution volume needed to support a refueling shutdown plus one cold shutdown from full power operation immediately following refueling. Additionally, each tank has the boric acid capacity that supports a plant cold shutdown assuming that the control rod with the highest reactivity worth is stuck in the fully withdrawn position.

Three holdup tanks are provided for storing the reactor coolant discharged from the RCS during plant startups, shutdowns, load changes, and boron dilutions. Normally, one tank receives reactor coolant, the second tank is the source of water sent to the boric acid evaporator for boron recovery, and the third tank is kept in standby. The combined capacity of the three tanks is designed to receive the total coolant discharged during a cold shutdown and unit restart at approximately 80% of the core cycle.

Chemical solutions for pH control and oxygen removal are mixed in and flushed from the chemical mixing tank. Slurries of fresh resin and makeup water are mixed in the resin fill tank and then sent to the demineralizers via flexible hoses.

6.2.3.4 Demineralizers

Two mixed-bed demineralizers containing mixtures of cation and anion resins are provided in the CVCS purification loop to maintain coolant purity. Each is sized to accept the full purification flow during normal operation and has a minimum design life of one core cycle.

One cation-bed demineralizer located downstream of the mixed bed demineralizers removes the Li-7 produced in the reactor coolant and maintains the desired pH of the reactor coolant. The demineralizer is sized to provide adequate purification flow to control the Li-7 concentration and/or the cesium concentration in the reactor coolant in the event of a fuel defect.

Two deborating demineralizers are used to compensate for fuel burnup near the end of core life. Anion resins remove boric acid from the reactor coolant.

One boric acid evaporator feed demineralizer removes lithium and ionic impurities in the reactor coolant feed to the boric acid evaporator.

6.2.3.5 Filters

Two cartridge-type reactor coolant filters remove particulates and resin fines larger than 25 microns in diameter in the letdown flow. Each filter is designed to accept the maximum purification flow.

One boric acid filter collects particulates, such as boric acid tank sediment from the boric acid solution makeup stream. The filter is designed to accept maximum makeup flow.

Two seal water injection filters remove particulates from the seal injection flow and thereby prevent foreign materials from entering the seals of the reactor coolant pumps.

Three mixed-bed demineralizer inlet filters remove particulates from the letdown flow and prevent the accumulation of particulates in the demineralizers. Two filters can be used in parallel to treat increased purification flow following a plant shutdown.

6.2.3.6 Letdown Orifices

Three equal-capacity letdown orifices, arranged in parallel, reduce the letdown pressure and control the flow of reactor coolant leaving the RCS. Two of the orifices are in service to provide normal-operation letdown flow. Each orifice is placed in service or isolated with a remotely controlled isolation valve located in series with it.

6.2.3.7 Boric Acid Evaporator

The boric acid evaporator removes nitrogen, hydrogen, and gaseous fission products from the reactor coolant, and processes coolant to increase the boron concentration to approximately 7,000 ppm so that it can be reused as boric acid makeup. The boric acid evaporator consists of the feed preheater, the gas stripper column, the vent condenser, the evaporator, the absorption tower, the condenser, the distillate pump, the distillate cooler, the concentrate pump, piping, valves, and instrumentation.

6.2.3.8 Boric Acid Blender

The boric acid blender mixes the concentrated boric acid solution with the primary makeup water to ensure thorough mixing of reactor coolant makeup.

6.2.3.9 Containment Isolation Valves

Containment isolation valves are located in the following lines:

- Letdown line,
- Charging line,
- Seal water return line, and
- Seal water injection line.

6.2.3.10 Relief Valves

The following relief valves are provided:

- Regenerative heat exchanger charging line relief check valve,
- Letdown relief valve,
- Letdown orifice relief valve,

- Volume control tank relief valve,
- Reactor coolant pump seal water return relief valve,
- Seal water heat exchanger inlet relief valve,
- Boric acid tank relief valve, and
- Holdup tank relief valve.

6.2.4 System Operation

6.2.4.1 Plant Startup

pH control is accomplished by injecting LiOH solution into the chemical mixing tank and flushing the solution with primary makeup water to the suction side of the charging pumps.

At the final stage of a plant heatup, the excess letdown line is utilized to increase the letdown flow to accommodate reactor coolant expansion.

Hydrazine is utilized for oxygen removal in the reactor coolant during a plant startup from cold conditions. The hydrazine solution is injected into the chemical mixing tank, where it is mixed with the primary makeup water. The hydrazine solution is supplied to the suction side of the charging pumps.

6.2.4.2 Normal At-Power Operation

At constant power levels, the CVCS purification loop operates continuously as a closed loop connected to the RCS. The purification flow is approximately 180 gpm with one mixed-bed demineralizer and one reactor coolant filter in service.

Normally, one charging pump is operating. It takes suction from the volume control tank and supplies the charging flow to the RCS and seal water injection to the reactor coolant pumps.

Control and scavenging of oxygen generated by water radiolysis in the core region is performed by supplying hydrogen to the reactor coolant. Hydrogen is supplied to the gas space of the VCT from the hydrogen manifold, and the required pressure of the gas space in the volume control tank is maintained by a hydrogen supply pressure control valve. This control valve can be adjusted to provide the appropriate equilibrium hydrogen concentration.

6.2.4.3 Plant Shutdown

During a plant shutdown, when the RHR system is in operation, the RHR system provides reactor coolant to the CVCS at a point upstream of the letdown heat exchanger in the letdown line. Cooling of the pressurizer fluids can be accomplished by charging through the auxiliary spray connection as an alternative to normal pressurizer spray.

When the purification flow is increased, two charging pumps can be in operation. The letdown flow passes through the letdown heat exchanger, two mixed-bed demineralizer inlet filters, two mixed-bed demineralizers, two reactor coolant filters, and two spray nozzles, and into the volume control tank. During a plant shutdown, the gas space of the volume control tank is replaced with nitrogen. The reactor coolant is returned to the RCS through the normal charging flow path.

6.2.4.4 Reactor Coolant System Leak

One CVCS charging pump is capable of maintaining the normal RCS inventory with a small system leak if the leakage rate is less than that from a 3/8-in.-diameter pipe break.

6.3 Component Cooling Water System

The component cooling water system provides cooling water required for various components during all plant operating conditions, including normal plant operating, abnormal, and accident conditions. It is an intermediate, closed-loop cooling system that transfers heat from the various components to the essential service water system.

6.3.1 Design Bases

6.3.1.1 Safety-Related Design Bases

The CCWS consists of two independent subsystems, with each subsystem providing 100% of the cooling capacity required for safe function. Each of the subsystems contains two 50%-capacity trains, for a total of four 50%-capacity trains.

The CCWS can be powered from either offsite or onsite Class 1E power supplies.

The CCWS is designed to perform its safety function of cooling safety-related components during accident mitigation assuming that one 50% train is out of service for maintenance coincident with the loss of offsite power and the failure of another train.

The CCWS is designed to have the capability to isolate the nonsafety-related portions of the system during accident mitigation.

The CCWS is designed against natural phenomena and internal missiles. The CCWS is protected against adverse environmental, operating, and accident conditions, such as flooding, a high-energy line break (HELB), thermal overpressurization, and water hammer.

The CCWS is designed to withstand leakage in one train without loss of the system's safety function.

The CCWS is designed to Seismic Category I requirements. The containment isolation valves and the piping between the isolation valves are designed and constructed to the requirements of ASME Section III, Class 2. The remainder of the system is designed and constructed to the requirements of ASME Section III, Class 3, except for the portion that is not required to perform safety functions.

6.3.1.2 Power Generation Design Bases

The CCWS is designed to:

- Serve as an intermediate system between components containing radioactive fluids and the ESWS, so as to prevent direct leakage of radioactive fluid into the environment through the ESWS,

- Provide sufficient cooling capacity for the components required during normal operating conditions such as normal power operation, normal shutdown, and refueling, and

- Detect leakage of radioactive material into the system and control leakage of radioactive material out of the system, and prevent long-term corrosion that may degrade system performance.

6.3.2 System Description

As shown in Figure 6-4, the CCWS is a closed-loop system that functions as an intermediate system between the various components cooled by the CCWS and the ESWS. The CCWS transfers heat, and prevents direct leakage of radioactive fluid from the cooled components, to the ESWS.

The CCWS consists of two independent subsystems. One subsystem consists of trains A and B, and the other subsystem consists of trains C and D, for a total of four trains. Each train has one CCW pump and one CCW heat exchanger and provides 50% of the cooling capacity required for the system's safety functions.

Electrical power to the CCWS is supplied from Class 1E buses that are backed up by Class 1E power supplies, so that the system is capable of operating during a loss of offsite power.

There is a header tie line between trains A and B, and another between trains C and D. Branching from the header tie line in each subsystem are the cooling water supplies to two sets of safety-related equipment (loops A and B [C and D]) and two sets of nonsafety-related equipment (loops A1 and A2 [C1 and C2]). See Table 6-4 for lists of the components supplied by each loop.

Each subsystem is served by one CCW surge tank. The CCW surge tank is installed at the highest point of the system to facilitate system air venting to ensure a water-solid closed loop and to provide the required net positive suction head at the CCW pump suctions. In addition, the surge tank accommodates the thermal expansion and contraction of the cooling water and potential leakage into or out of the CCWS.

6.3.3 Component Descriptions

Design parameters for major components of the CCWS are provided in Table 6-5.

6.3.3.1 CCW Heat Exchangers

The plate-type CCW heat exchangers transfer heat from the CCWS to the ESWS.

6.3.3.2 CCW Pumps

Each CCW pump circulates cooling water through a CCW heat exchanger and several components cooled by the CCWS. The pumps are horizontal, centrifugal pumps driven by ac-powered induction motors.

6.3.3.3 CCW Surge Tanks

The CCW surge tanks are connected to the suctions of the CCW pumps. The surge tanks accommodate the thermal expansion and contraction of the cooling water and potential leakage into or from the CCWS. The makeup water connections are made to the tank surge lines.

In the case of a small leak out of the system, makeup water is supplied as necessary until the leak is isolated. The makeup water can be supplied from one of the following systems:

- Demineralized water system,
- Primary makeup water system, or
- Refueling water storage system.

Deaerated water is used for initial filling of this system and demineralized water is used for automatic makeup when a tank's water level reaches the low-level setpoint. If necessary, primary makeup water or refueling water may be used during an emergency.

Water chemistry control of the CCWS is performed by adding chemicals to the CCW surge tanks to prevent long-term corrosion that may degrade system performance. The water in the surge tanks is covered with nitrogen gas to maintain water chemistry.

In order to provide redundancy for a passive failure (a loss of system integrity resulting in abnormal leakage), an internal partition plate is provided in each tank so that two separate surge tank volumes are maintained.

6.3.3.4 Piping

Carbon steel is used for the piping of the CCWS. Piping joints and connections are welded, except where flanged connections are required.

6.3.3.5 Major Valves

Header Tie Line Isolation Valves: The function of these motor-operated valves (two per tie line) is to separate each subsystem into two independent trains during abnormal and accident conditions. This feature ensures that each safety train is isolated from any potential passive failure in the nonsafety-related portion or in another safety train of the CCWS. Each valve automatically closes in response to the following signals:

- Low-low water level signal from the associated subsystem’s surge tank,
- Emergency core cooling system (ECCS) actuation signal coincident with a Class 1E bus undervoltage signal, or
- Containment spray actuation signal.

Containment Spray/Residual Heat Removal Heat Exchanger CCW Outlet Valves: Each of the four normally closed motor-operated valves automatically opens in response to an ECCS actuation signal, coincident with a start signal for the associated train’s CCW pump, to establish cooling water flow to the associated CS/RHR heat exchanger.

Reactor Coolant Pump Thermal Barrier Heat Exchanger CCW Return Line Isolation valves: The two motor-operated valves located in the CCW outlet line of each RCP thermal barrier heat exchanger close automatically in response to a high flow rate sensed in the line, which would result from reactor coolant leakage into the CCWS through the thermal barrier heat exchanger.

CCW Surge Tank Vent Valves and Relief Valves: Each surge tank’s vent valve opens in response to high CCW surge tank pressure and closes in response to a high radiation level sensed in the associated CCWS subsystem. Each surge tank’s relief valve provides surge tank overpressure protection.

Containment Isolation Valves: Containment isolation valves are installed on CCW lines penetrating containment.

Isolation valves Between Seismic Category I and Nonseismically Qualified System Portions: Air-operated isolation valves are provided in each CCW supply line to the components located in the non-Seismic Category I buildings (turbine building and auxiliary building). These valves automatically close in response to appropriate signals to protect against out-leakage from the CCWS Seismic Category I portions through the nonseismic portions. Out-leakage through the nonseismic CCWS return lines is prevented by check valves in the return lines.

6.3.4 System Operation

6.3.4.1 Normal At-Power Operation

During normal operation, at least one train of each subsystem is in service. A total of two CCW pumps and two CCW heat exchangers are in operation. The combination of trains in service is train A or B and train C or D. The operating CCW pump in each subsystem supplies cooling water at less than 100°F to all loops supplied by that subsystem. The CCW pumps which are not in service are in standby. A standby pump automatically starts in response to low pressure sensed in a CCW header.

Normal operating loads include the reactor coolant pumps, charging pumps, letdown heat exchanger, instrument air system, spent fuel pool cooling heat exchanger, sample heat exchanger, seal water heat exchanger, blowdown sample cooler, boric acid evaporator evaporator, and waste gas compressor. The CCWS provides sufficient surge tank capacity below that corresponding to the low level alarm setpoint to allow for operators to take action.

6.3.4.2 Normal Plant Shutdown

After approximately four hours of normal plant cooldown, when the reactor coolant temperature and pressure have been reduced to approximately 350°F and 400 psig, the standby CCW heat exchangers and pumps are placed in service, resulting in four trains (four CCW pumps and four CCW heat exchangers) in operation. The CCWS isolation valve for each of the CS/RHR heat exchangers is opened to supply cooling flow.

The failure of one cooling train (failure in one pump or one heat exchanger) increases the time for plant cooldown, but it does not affect the safe operation of the plant. The plant can be brought safely to the cold shutdown condition with a minimum of two trains.

During a plant cooldown by the residual heat removal system, the CCW supply temperature to the various components is permitted to increase to 110°F.

6.3.4.3 Refueling

During refueling, the required number of operating CCW heat exchangers and pumps is determined by the heat load. Normally, three trains operate in this mode. The remaining train may be taken out of service for maintenance. Operating CCW pump(s) in each subsystem supply cooling water at less than 100°F to all loops in service in that subsystem.

6.3.4.4 Loss-of-Coolant Accident

All CCW pumps are automatically actuated by an ECCS actuation signal. The isolation valves for the CS/RHR heat exchangers are automatically opened by an ECCS actuation signal, coincident with start signals for the CCW pumps. The header tie line isolation valves are closed by an ECCS actuation signal in coincidence with an undervoltage signal, and the CCWS is separated into four individual trains (A, B, C and D). The header tie line isolation valves can be manually reopened from the main control room to restore RCP seal and spent fuel pit heat exchanger cooling, if required. At least two trains are required to operate to sufficiently mitigate a LOCA.

6.3.4.5 Loss of Offsite Power

In the case of an LOOP, all CCW pumps are automatically loaded onto their respective Class 1E power sources. The CCWS continues to provide cooling water to the required components. At least two trains are required to operate during an LOOP.

6.3.4.6 Leakage from Higher Pressure Components into the CCWS

If leakage from a higher pressure component to the CCWS should occur, the water level of a CCW surge tank increases, and the high level is annunciated in the main control room. If the in-leakage is radioactive, the increased radiation level in the CCWS is also indicated in the main control room. An alarm is generated when the radiation level reaches its high setpoint. After the leak source is identified, the leak is isolated from the CCWS.

In the event that the in-leakage is through an RCP’s thermal barrier heat exchanger, the isolation valves in that thermal barrier heat exchanger CCW return line are automatically closed by a high flow rate signal, thereby preventing further CCWS contamination.

6.3.4.7 Leakage from the CCWS

A decrease in CCW surge tank water level to the low-level setpoint initiates automatic makeup to the surge tank and an alarm in the main control room, indicating a system leak. After the leak source is identified, the leak is isolated. If the water level of the surge tank further decreases to the surge tank low-low water level setpoint, another alarm is generated, and the header tie line isolation valves for that subsystem automatically close. Since the subsystem consists of two individual trains, the train with the leak can be isolated, and the other train can be operated.

6.4 Essential Service Water System

The essential service water system provides cooling water to remove heat from the component cooling water heat exchangers and the essential chiller units. The ESWS transfers the heat from these components to the ultimate heat sink (UHS).

6.4.1 Design Bases

6.4.1.1 Safety-Related Design Bases

The system, in conjunction with the plant’s UHS, is designed to remove heat from the plant auxiliaries required to mitigate the consequences of a design-basis event and for safe shutdown, assuming a single failure and one train unavailable due to maintenance coincident with a loss of offsite power. The essential service water pumps are designed to perform their safety function with the lowest probable water level of the UHS.

The system is designed to detect radioactive in-leakage and to preclude the release of radioactive contaminants to the environment. Radioactive contaminants may enter the ESWS from the component cooling water system.

The system design incorporates protection against potential adverse environmental, operating, and accident conditions, such as freezing, thermal overpressurization, and water hammer. The safety-related portions of the ESWS are protected against wind and tornado effects, floods, missiles, and postulated piping ruptures.

The ESWS is constructed in accordance with ASME Section III, Class 3, Seismic Category 1 requirements.

6.4.1.2 Power Generation Design Basis

The ESWS removes heat from the CCWS through heat exchange in the CCWS heat exchangers and from the essential chiller units during normal plant operation, refueling, and normal shutdown. The ESWS does not provide cooling water to any nonsafety-related components during normal plant operations or design -basis LOCA conditions.

6.4.2 System Description

As shown in Figure 6-5, the essential service water (ESW) pumps draw water from the intake basin, direct it through the CCW heat exchangers and the essential chiller units, and return it to the UHS. The UHS is the source of water to the intake basin. The essential chiller units do not contain radioactive fluid, and the CCWS is the intermediate loop between the reactor auxiliaries and the ESWS. This arrangement minimizes direct leakage of radioactive fluid from the ESWS to the environment. Nevertheless, the CCW plate-type heat exchangers are constructed to prevent intermixing of the fluids, so that any leakage goes to the outside of the heat exchanger except when a hole is developed in a plate - a rare event with titanium plates. Gasket failure directs leakage toward the outside of the CCW heat exchanger; hence radioactive contamination of the ESWS propagating to the UHS and ultimately to the environment is not considered credible. Any leakage from the CCW heat exchangers is collected into the nonradioactive floor drains, thus ensuring that no ESWS water is released directly to the environment. In addition, an ESWS radiation monitor is provided downstream of each CCW heat exchanger. The monitors alert the operator to in-leakage from the CCWS so that he can isolate the leaking train.

The ESWS is arranged into four independent trains (A, B, C, and D). Each train consists of one ESW pump, two 100%-capacity strainers in the pump discharge line, one 100%-capacity strainer upstream of the CCW heat exchanger, one CCW heat exchanger, one essential chiller unit, and associated piping, valves, instrumentation, and controls.

Each line supplies cooling water to the essential chiller unit in a power source building and the CCW heat exchanger in the reactor building. The supply lines pass through ESW tunnels before entering the reactor and power source buildings. Each CCW heat exchanger is provided with piping and isolation valves around the heat exchanger which permit back flushing of the ESW side when required. Return flow from each ESW train to the UHS is via an independent line.

The per-train ESW flow of 13,000 gpm is maintained for all operating conditions. The ESWS is designed to operate with water temperatures as low as 32°F. The ESWS layout ensures that the fluid pressure in the system is above saturation conditions at all locations. This feature, in combination with the control of the pump discharge valves, minimizes the potential for transient water hammer.

The type and location of the UHS are site specific. The COL applicant's selection and design of the UHS ensure that the flow rate delivered to the ESWS does not exceed the maximum design temperature of 95°F under all operating conditions to assure sufficient cooling capacity. The UHS design also assures a minimum 30-day cooling water inventory without makeup to mitigate the consequences of a design-basis event. The COL applicant is to design the UHS basin such that the minimum water level after 30 days of emergency operation provides adequate NPSH to the ESW pumps under accident conditions.

Biofouling and chemistry control of the ESWS is site specific and depends on the type of UHS. The COL applicant is to specify the following ESW chemistry requirements:

- A chemical injection system to provide noncorrosive, nonscale-forming conditions to limit biological film formation, and
- The types of biocide, algaecide, pH adjuster, corrosion inhibitor, scale inhibitor, and silt dispersant based on the site conditions.

6.4.3 Component Descriptions

Table 6-6 shows the design parameters for the major components in the system.

6.4.3.1 ESW Pumps

Four 50%-capacity ESW pumps, one per train, supply cooling water to remove heat from the cooled components and then discharge it to the UHS. The pumps are powered from the Class 1E normal ac power system. On a loss of offsite power, the pumps are automatically powered from their respective emergency power sources.

Approximately 12,043 gpm of pump flow is required for all modes of plant operation. This provides an approximate 7.7-percent margin to the design pump flow rate of 13,000 gpm. The margin allows for pump and heat transfer degradation by fouling, leakage, excessive pressure drops across system components, or fluctuations due to supplied electrical frequency.

The COL applicant is to determine the site-specific design data for the pumps and the mode of cooling for the pump motors.

6.4.3.2 Strainers

Two 100%-capacity parallel strainers are located in each ESW pump discharge line. The strainers are the automatic self-cleaning type. The differential pressure across the operating strainer is monitored. When the predetermined high differential set pressure across the strainer is reached, an alarm is sent locally and to the main control room. A high differential pressure alarm initiates backwashing of the accumulated debris inside the strainer. The backwash operation is started before the maximum allowable differential pressure is reached to prevent strainer clogging. During normal operations, the operator may also periodically operate the standby or parallel strainer in lieu of the normally operating strainer of that train.

The automatic strainers have a three-mm mesh, which is considered to effectively remove debris from the system that could clog the CCW plate heat exchangers, which have flow passages approximately three to six mm in diameter. Since the essential chiller units, being shell-and-tube-type heat exchangers, have much larger flow paths than the CCW heat exchangers, no strainers for additional filtering are deemed necessary. The three-mm mesh of the strainer elements also assures that potential clogging of the cooling tower nozzles is avoided.

6.4.3.3 Heat Exchangers

The ESWS includes four 50%-capacity plate-type CCW heat exchangers, one per train, and four 50%-capacity chiller units, one per train.

6.4.3.4 Piping

Carbon steel piping designed, fabricated, installed and tested in accordance with ASME Section III, Class 3 requirements, is used for the safety-related portion of the ESWS. The piping located in trenches is externally lined carbon steel; the lining material specification is appropriate to the site soil chemistry. The rest of the ESWS piping is carbon steel or internally lined carbon steel, depending on ESWS water chemistry requirements. Cathodic protection is provided for buried piping. Manholes are provided for periodic piping inspection.

6.4.3.5 Valves

The water in the ESWS does not normally contain radioactivity, and therefore, special provisions for protection against leakage to the atmosphere are not necessary. Isolation valves are provided upstream and downstream of each component to facilitate its removal from service.

A motor-operated valve is provided at the discharge of each pump. The starting logic of each ESW pump interlocks the motor-operated valve with the pump operation. The initially closed discharge valve opens after the pump has started. This feature minimizes the transient effects that may occur as the developed flow sweeps out air that may be present in the system.

Each CCW heat exchanger is provided with two separate, normally locked-closed isolation valves and piping around the heat exchanger for back flushing. One valve is located in the piping which runs from immediately upstream of the heat exchanger inlet isolation valve to immediately upstream of the heat exchanger discharge isolation valve, and the second valve is located in the piping which runs from immediately downstream of the heat exchanger inlet isolation valve to immediately downstream of the heat exchanger discharge isolation valve. To initiate back-flush operation, both bypass valves are opened, and the heat exchanger isolation valves are closed. With that lineup, ESW flow enters what is normally the discharge side of the heat exchanger and exits the heat exchanger from what is normally the inlet side to the ESW discharge line.

6.4.4 System Operation

6.4.4.1 Normal At-Power Operation

Normally two ESW trains are in operation, and at least one other train is in standby. The in-service ESW trains correspond to the in-service CCW trains. A maximum ESW operating temperature of 95°F, based on the bounding meteorological and water-source conditions from representative locations in the United States, has been evaluated to adequately remove CCW heat exchanger heat loads at all operating conditions.

The ESW pump operation, ESW header pressure signals, and CCW pump operation are interlocked to enable automatic start and stop functions of the ESW pumps and CCW pumps. A low ESW header pressure signal due to failure or tripping of an operating ESW pump is alarmed in the main control room. When the low ESW header pressure alarm is annunciated, the standby ESW pump and the standby CCW pump of the same train designation start automatically, ensuring continuous heat removal. In the same manner, a low CCW supply header pressure signal accompanied by a start signal for the CCW pump in the same train will automatically start the corresponding ESW pump. This indicates that an operating CCW pump has failed and requires the alternate (or standby) ESW pump and CCW pump in another train to start.

Voiding in any train may occur with a loss of offsite power and subsequent pump trip. In order to preclude water hammer on pump restart, the motor-operated valve at the discharge of each pump is interlocked to close when the pump is not running or tripped. This interlock prevents the pump from starting if the valve is not closed. The valve starts to open after the respective pump starts.

Radioactive leakage from the CCWS into an ESWS train is detected by the radiation monitor located downstream of the CCW heat exchanger. The high radiation level is alarmed in the main control room. The operator manually isolates the contaminated ESWS train and the corresponding CCWS train by stopping the ESW and CCW pumps, thus taking the contaminated CCW heat exchanger out of service. Standby CCWS and ESWS trains are placed in service. The manual isolation valves on each side of the CCW heat exchanger are also closed to ensure that the radioactive leakage is not circulated in the ESWS and eventually discharged to the UHS.

6.4.4.2 Loss-of-Coolant Accident

All ESW pumps are automatically started by an ECCS actuation signal. They supply cooling water to their respective CCW heat exchangers and essential chiller units. When offsite power is not available, the ESW pumps are automatically powered by the onsite Class 1E power supplies. At least two trains of the ESWS are required to operate to sufficiently mitigate a LOCA.

6.4.4.3 Loss of Offsite Power

When offsite power is lost, all ESW pumps are powered by onsite Class 1E power supplies, which are automatically started by the Class 1E bus undervoltage signal. During this condition, a minimum of two trains of the ESWS are required to operate.

6.5 Spent Fuel Pit Cooling and Purification System

The spent fuel pit cooling and purification system performs the following functions:

- Maintaining the SFP water temperature by removing the decay heat generated by spent fuel assemblies in the SFP,
- Purifying and clarifying the SFP water,
- Purifying the borated water for the refueling water storage pit, the refueling cavity, and the refueling water storage auxiliary tank,
- Transferring borated water to the fuel transfer canal, fuel inspection pit, and cask pit in conjunction with the refueling water system, and
- Supplying borated water to the chemical and volume control system charging pumps as an alternate water source.

6.5.1 Design Bases

The cooling portion of the SFPCS is classified as equipment class 3, is safety related, and is designed in accordance with ASME Code Section III, Class 3, Seismic Category I requirements.

With both SFPCS trains in operation, the system is designed to maintain the SFP water temperature below 120°F during a partial core offload with a fully loaded SFP and the heat load from the previously discharged spent fuel and the newly offloaded partial core. In the case of an SFPCS single active failure, the system is designed to maintain the SFP water temperature below 140°F.

The system, using two SFPCS trains in conjunction with two trains of the RHRS, is designed to maintain the SFP temperature below 120°F during a full-core offload with a fully loaded SFP and the heat load from the previously discharged spent fuel and the newly offloaded full core. In the case of any single active failure, the system is designed to maintain the SFP water temperature below 140°F.

The system is designed to purify the contents of the SFP, the refueling cavity, the RWSAT, and the RWSP without causing any interruption in a refueling operation. The purification portion of the SFPCS (piping, demineralizers, and filters) is not safety related.

The SFPCS provides heat removal for the pit water by circulating the pit water with the SFP pump(s) and transferring the spent fuel's decay heat to the CCWS in the SFP heat exchangers.

The cooling portion of the SFPCS is protected against natural phenomena and internal and external missiles.

The system piping is arranged such that the failure of any line cannot drain the SFP water level below a point 11 ft, 1 in. above the top of the stored fuel assemblies, which is the minimum SFP water level that provides adequate shielding.

The SFPCS is designed to collect system leakage. A liner collection system to the reactor building sump is provided to collect possible leakage from the SFP liner plate welds on the pit walls and floor. Leakage from the system piping is collected in the reactor building sump.

The shielding provided by the SFP water limits the radiation dose at the surface of the SFP.

6.5.2 System Description

The SFPCS, which consists of two 100%-cooling-capacity trains, is shown in Figure 6-6. Each train includes one SFP pump, one SFP heat exchanger, one SFP filter, and one SFP demineralizer. In addition, each train of equipment has its own suction and discharge headers and includes the piping, valves, and instrumentation necessary for system operation.

Each SFPCS train contains a cooling portion for cooling of the circulated SFP water and a purification portion for purification of the borated water in the SFP, RWSP, RWSAT, and refueling cavity. The SFPCS is designed such that either train can be operated to perform all the functions required of the system, independently of the other train. Normally, one train is continuously cooling and purifying the SFP water while the other train is available for water transfers, for refueling water storage purification, or as a backup to the operating train. A portion of the SFP pump discharge is diverted through the demineralizers and filters in the purification portion of the system and returned to the SFP. The demineralizers and filters remove particulate and ionic impurities from the SFP water.

Each train's suction line, which is protected by a strainer, is connected to the SFP at an elevation approximately 4 ft below the normal SFP water level. The return line contains a siphon breaker located near the surface of the water. These features are provided so that the pit cannot be gravity drained below a point 11 ft, 1 in. above the top of the spent fuel assemblies.

To remove decay heat from the spent fuel, the operating SFP pump circulates SFP water through the SFP heat exchanger, where heat is transferred to the CCWS. For purification of the SFP water, approximately 265 gpm is bypassed from the cooling portion of the SFPCS into the purification portion's demineralizer and filter, where dissolved impurities and solid materials are removed, respectively. Isolation valves are provided to permit isolation of the purification portion from the cooling portion to allow purification of the water in the refueling cavity, the RWSAT, or the RWSP in parallel with SFP cooling operation.

When the heat load of the SFP is high (for a full-core offload), two RHRS trains (A and D), each including a CS/RHR pump and a CS/RHR heat exchanger, perform SFP cooling in conjunction with the two SFP cooling loops.

The SFP is initially filled with water with a boron concentration of approximately 4,000 ppm. The borated water is supplied from the RWSP to the SFP by a refueling water recirculation pump, or directly supplied via a temporary pipe connected to the outlet of the boric acid blender in the CVCS.

In the unlikely event that the spent fuel cooling portion of the SFPCS fails, the SFP water temperature would rise, followed by an increase in evaporative losses from the SFP. Minor leakage from SFPCS piping or components or from the SFP liner also decreases the SFP water level. Makeup to the SFP is manually started upon receipt of a low-level alarm signal in the MCR. These losses could be made up from one of the following water sources:

- The safety-related borated water source is the RWSP, a Seismic Category I structure. The RWSP contents are borated to 4,000 ppm, matching the boron concentration of the SFP. The makeup line from the RWSP to the SFP is designed to Seismic Category I, ASME Code Section III, Class 3 requirements.

- As a backup to the safety-related makeup source, a makeup line is also provided from the emergency feedwater (EFW) pit tie line to the SFP. The EFW pits are also Seismic Category I structures, but the makeup line from the EFW pits to the SFP is not seismically qualified.

- Makeup water can also be added to the SFP from the demineralized water system. The water source is a nonseismically qualified demineralized water storage tank, and the makeup line from the water source to the SFP is also not seismically qualified.

The SFP is isolated from the fuel transfer canal (integrated structure with the fuel inspection pit) by a gate. This gate is provided to allow the fuel transfer canal to be drained during maintenance of the fuel transfer equipment. The fuel transfer canal is drained by transferring the water to the SFP with a fuel transfer canal pump. To maintain an adequate water level in the SFP during this operation, excess pit water is discharged into the RWSP or the RWSAT with the operating SFP pump via a purification loop.

6.5.3 Component Descriptions

The SFPCS component design parameters are provided in Table 6-7.

6.5.3.1 Spent Fuel Pit Pumps

Two identical pumps are installed in parallel in the SFPCS. Each pump is sized to circulate the pit water through an SFP heat exchanger in conjunction with a demineralizer and filter to perform purification and cooling of the SFP water. The SFP pumps are of the horizontal, centrifugal type, and the wetted surfaces in contact with the fuel pit water are constructed of stainless steel.

6.5.3.2 Spent Fuel Pit Heat Exchangers

Two SFP heat exchangers are provided to remove decay heat from the SFP. These heat exchangers are plate-type heat exchangers constructed of austenitic stainless steel. SFP water circulates through one side of each heat exchanger, while component cooling water circulates through the other side.

6.5.3.3 Spent Fuel Pit Filters

Two vertical, cylindrical cartridge-type SFP filters are provided in the purification portion of the SFPCS. Each cartridge filter is designed for a flow rate of approximately 265 gpm. The filter improves the pit water clarity by removing solid particles. The filter assembly is constructed of austenitic stainless steel with disposable filter cartridges.

6.5.3.4 Spent Fuel Pit Demineralizers

Two vertical, cylindrical demineralizers are provided. Each demineralizer is designed for a flow rate of approximately 265 gpm. Each demineralizer removes ionic impurities from the SFP water. The vessels are constructed of austenitic stainless steel.

6.5.3.5 Spent Fuel Pit Strainers

SFP strainers are provided in the pump suction piping to remove relatively large solid materials for SFP pump and CS/RHR pump protection. The strainers are made of stainless steel.

6.5.3.6 Valves

Manual valves are used to isolate the cooling portion of the SFPCS from the purification portion. Manual valves are used to isolate components that could develop leaks or failures. Manual throttle valves are provided for flow control. Valves in contact with SFP water are made of stainless steel.

6.5.3.7 Piping

All piping in contact with SFP water is made of stainless steel. The piping is welded, except for flanged connections for the pumps and heat exchangers.

6.5.3.8 Spent Fuel Pit

The SFP is located within the Seismic Category I reactor building fuel handling area. The walls of the SFP are integral parts of the reactor building structure. The facility is protected from the effects of natural phenomena such as earthquakes, wind and tornados, floods, and external missiles. The facility is designed to maintain its structural integrity following a safe-shutdown earthquake and to perform its intended function following a postulated event such as a fire.

The refueling canal is connected on one side to the SFP. On its opposite side, the refueling canal connects to the spent fuel cask loading pit and to the fuel inspection pit. A weir and gate provide physical isolation of the refueling canal from each of the three pits. All the gates are normally closed and only opened as required.

Moderate density racks containing neutron-absorbing material are provided in the SFP. SFP design parameters are provided in Table 6-8.

6.5.4 System Operation

6.5.4.1 Plant Startup, Normal Operation, and Shutdown

During plant startups, normal plant operation, and shutdowns, one SFPCS train is normally operating. The operating train is aligned to provide SFP cooling and purification. The other train is available to perform the other system functions, such as RWSP or RWSAT purification and water transfers. If the operating SFPCS train is lost, then the other train should be placed in service before the pit water high-temperature alarm is received.

The SFP water chemistry can be checked at local sample points. If purification is required, a portion of the system flow is diverted through an SFP demineralizer and filter and returned to the pit. Local sample connections are provided in the SFP demineralizer inlet and outlet lines to check the boron concentration and radioactivity of the circulated water, and to evaluate the effectiveness of the filters and demineralizers.

6.5.4.2 Refueling

The SFPCS has its maximum duty during refueling operations, when the decay heat from the spent fuel is highest. The SFPCS standby train is normally placed in service during refueling operations; it continues in operation as long as required to maintain temperature and water purity within the prescribed limits.

Two purification trains are constantly operating in tandem with two cooling trains for purification and cooling of the SFP water during normal operations. One purification train is isolated from the cooling portion to utilize it for purification of the refueling cavity contents at an early stage of the refueling operation. From reactor disassembly to fuel offload initiation, the two SFPCS cooling trains are in service, with one SFPCS purification train utilized for refueling cavity purification. After the completion of the refueling operation, that purification train is returned to its SFP water purification function, if deemed necessary.

Prior to refueling, the SFP water is checked to verify that its boron concentration is equivalent to that of the RWSP contents.

Partial Core Offload: The two SFPCS trains are designed with the capacity to remove the spent-fuel decay heat generated from the accumulation previously offloaded cores and from the most recently irradiated partial core, which is completely transferred into the SFP at 120 hours after plant shutdown. The SFPCS is designed to maintain the pit water temperature below 120°F with two trains operating. In the case of a single active component failure (e.g., one SFP pump or CCW pump failure), the SFPCS is designed to maintain the pit water temperature below 140°F with one operating SFPCS train.

The decay heat generated from the accumulation of 10 years of spent fuel, plus that of the most recently irradiated half core, which has just been placed in the pool beginning about 120 hours after reactor shutdown, is 50.8 x 10^6 BTU/hr.

Full-Core Offload: In the case of a full-core offload, the SFP is aligned to RHRS trains A and D. Each train includes one CS/RHR pump and one CS/RHR heat exchanger. RHRS trains A and D and the two SFPCS cooling trains maintain the pit water temperature below 120°F by removing the spent-fuel decay heat generated from the accumulation of previously offloaded cores and from the recently offloaded full core, which is completely transferred into the SFP at 120 hours after plant shutdown. The SFPCS is designed to maintain the pit water temperature below 140°F assuming a single active component failure (e.g., one SFP pump, CS/RHRS pump, or CCW pump failure).

6.5.4.3 Spent Fuel Pit Purification

Each purification loop (one for each SFP cooling train) has the capacity to perform purification of the borated water in the SFP, the refueling cavity, the RWSAT, and the RWSP without causing any interruption to a refueling operation. The system's demineralizers and filters provide adequate purification to achieve the following:

- Minimizing the SFP surface dose rate during normal fuel handling operations and anticipated accident conditions in the spent fuel storage area so as to permit access of plant personnel, and

- Maintaining the optical clarity of the SFP water. The SFPCS clarification capability is sufficient to permit the necessary operations that must be conducted in the SFP area.

Each purification loop contains a filter vessel with a disposable cartridge filter downstream of a mixed-bed demineralizer. Each purification loop is designed for a flow rate of 265 gpm. This design flow rate is sufficient to maintain the specified water chemistry.

Table 6-1 RHRS Equipment Design Parameters

Containment Spray/Residual Heat Removal Pump	
Number	4
Type	Horizontal, centrifugal type
Power Requirement (kW)	400
Design Flow Rate (gpm)	3,000
Design Head (ft)	410
Minimum Flow Rate (gpm)	355
Maximum Flow Rate (gpm)	3,650
Design Pressure (psig)	900
Design Temperature (° F)	400
Material	Stainless Steel
Normal Operating Temperature (° F)	32 ~ 356
Fluid	Reactor coolant, Boric acid water
Radioactive Concentration (kBq/cm^3)	≥ 37
NPSH Available	17.9 ft at 3,650 gpm
NPSH Required	16.4 ft at 3,650 gpm
Equipment Class	2

Containment Spray / Residual Heat Exchanger		
Number	4	
Type	Horizontal U-tube type	
Heat Transfer Rate (Btu/h)	17.1×10^6	
Overall heat Transfer Coefficient and the effective heat transfer area, UA (Btu/h/° F)	1.852×10^6	
	Tube side	Shell side
Design Pressure (psig)	900	200
Design Temperature (° F)	400	200
Design Flow Rate (lb/h)	1.5×10^6	2.2×10^6
Design Inlet Temperature (° F)	120	99.7
Design Outlet Temperature (° F)	108.7	107.4
Material	Stainless steel	Carbon Steel
Fluid	Reactor coolant, boric water	Component cooling water
Radioactive Concentration (kBq/cm^3)	≥ 37	<37
Equipment Class	2	3

Table 6-2 Chemical and Volume Control System Parameters During Normal Plant Operation

Seal water supply flow rate	32 gpm
Seal water return flow rate	12 gpm
Normal letdown flow rate (Note)	180 gpm
Normal charging flow rate	160 gpm
Temperature of letdown water at full power	552.6° F (at normal letdown flow)
Temperature of charging water at full power	464° F (at normal letdown flow)
Temperature of coolant discharged to the holdup tanks	115° F
Charging pumps mini flow	70 gpm

(Note) US-APWR has two letdown mode of 90gpm and 180gpm (maximum) and normally operated at 180gpm.

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 1 of 6)

Charging Pumps		
Number of units	2	
Design flow rate	275 gpm	
Type	Multistage horizontal centrifugal	
Design pressure	3,185 psig	
Design temperature	200° F	
Fluid	Reactor coolant	
Material	Stainless steel	
B.A. Transfer Pumps		
Number of units	2	
Type	Horizontal centrifugal	
Design flow	130 gpm	
Design pressure	200 psig	
Design temperature	200 °F	
Fluid	Boric acid water (approximately 7,000 ppmB)	
Material	Stainless steel	
B.A. Evaporator Feed Pumps		
Number of units	2	
Type	Horizontal centrifugal	
Design flow (process operation)	45 gpm	
Design flow (circulation operation)	130 gpm	
Design pressure	200 psig	
Design temperature	200° F	
Fluid	Reactor coolant	
Material	Stainless steel	
Regenerative Heat Exchanger		
Number of units	1	
Heat Transfer rate	27.4×10^6 BTU/h	
Type	Shell and tube type	
	Shell Side (Letdown)	Tube Side (Charging)
Design pressure	2485 psig	3185 psig
Design temperature	650 ° F	650 ° F
Design Flow rate	8.95×10^4 lb/h	7.98×10^4 lb/h
Design Inlet temperature	552.6° F	130.0° F
Design Outlet temperature	271.0° F	464.0° F
Material	Stainless steel	Stainless steel

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 2 of 6)

Letdown Heat Exchanger		
Number of unit	1	
Type	Single-shell pass U-tube	
Heat exchanger rate	24.2 x 10^6 BTU/H	
	Shell Side (CCW)	Tube side (Reactor coolant)
Design pressure	200 psig	700 psig
Design Temperature	300 ° F	400 ° F
Design flow rate	6.5 x 10^5 lb/h	8.95 x 10^4 lb/h
Design Inlet temperature	100° F	380° F
Design Outlet temperature	137.7° F	115° F
Material	Carbon steel	Stainless steel
Excess Letdown Heat Exchanger		
Number of unit	1	
Type	Vertical U-bend tube type	
Heat transfer rate	5.11 x 10^6 BTU/h	
	Shell side	Tube Side
Design pressure	200 psig	2485 psig
Design Temperature	300° F	650° F
Design Flow rate	1.37 x 10^5 lb/h	1.24 x 10^4 lb/h
Inlet temperature	100 ° F	552.6 ° F
Outlet temperature	137.4 ° F	165.0 ° F
Material	Carbon steel	Stainless steel
Seal Water Heat Exchanger		
Number of unit	1	
Type	Horizontal U-bend tube type	
Heat transfer rate	1.77 x 10^6 BTU/h	
	Shell Side	Tube Side
Design pressure	200 psig	150 psig
Design temperature	200° F	200° F
Design flow rate	1.25 x 10^5 lb/h	5.6 x 10^4 lb/h
Inlet temperature	100 ° F	146.7 ° F
Outlet temperature	113.5 ° F	115 ° F
Material	Carbon steel	Stainless steel

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 3 of 6)

Cation Bed Demineralizer	
Number of units	1
Type	Vertical cylindrical
Resin volume	30 ft^3
Vessel capacity	45 ft^3
Design pressure	300 psig
Design temperature	150° F
Design flow	110 gpm
Material	Stainless steel
Deborating Demineralizer	
Number of units	2
Type	Vertical cylindrical
Resin volume	70 ft^3
Vessel capacity	100 ft^3
Design pressure	300 psig
Design temperature	150° F
Design flow	180 gpm
Material	Stainless steel
B.A. Evaporator Feed Demineralizer	
Number of units	1
Type	Vertical cylindrical
Resin volume	70 ft^3
Vessel capacity	100 ft^3
Design pressure	200 psig
Design temperature	200° F
Design flow	45 gpm
Vessel material	Stainless steel
B.A. Evaporator	
Number of units	1
Capacity	30 gpm
Material	Stainless steel
B.A. Blender	
Number of units	1
Fluid	Boric acid water (approximately 7,000 ppmB)
Design pressure	200 psig
Design temperature	200° F
Material	Stainless steel

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 4 of 6)

Volume Control Tank	
Number of units	1
Capacity	670 ft^3
Type	Vertical cylindrical
Design pressure (internal)	75 psig
Design pressure (external)	15 psig
Design temperature	200° F
Material	Stainless steel
Boric Acid Tanks	
Number of units	2
Type	Vertical cylindrical
Capacity	66,000 gal
Design pressure	7 psig
Design temperature	200° F
Fluid	Boric acid water (approximately 7,000 ppmB)
Material	Stainless steel
Holdup Tanks	
Number of units	3
Type	Vertical cylindrical type
Capacity	16,000 ft^3 (0 to approximately 100% level)
Design pressure	15 psig
Design temperature	200° F
Fluid	Reactor coolant drain
Material	Stainless steel
RCP Purge Water Head Tank	
Number of units	1
Type	Horizontal cylindrical type
Capacity	46 ft^3 (0 to approximately 100% level)
Design pressure (internal)	25 psig
Design pressure (external)	15 psig
Design temperature	200° F
Fluid	Primary makeup water
Material	Stainless steel
Resin Fill Tank	
Number of units	1
Type	Vertical cone type
Capacity	21 ft^3
Design pressure	Atmosphere
Design temperature	150° F
Fluid	Resin slurry
Material	Stainless steel

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 5 of 6)

Chemical Mixing Tank	
Number of units	1
Type	Vertical Cylindrical
Capacity	0.67 ft^3
Design pressure	200 psig
Design temperature	150° F
Fluid	LiOH, Hydrazine, etc.
Material	Stainless steel
Boric Acid Batching Tank	
Number of units	1
Type	Vertical Cylindrical
Capacity	1,050 gallon
Design pressure	Atmosphere
Design temperature	200° F
Fluid	Boric acid water (approximately 7,000 ppmB)
Material	Stainless steel
Reactor Coolant Filter	
Number of units	2
Type	Disposable cartridge [250gpm type]
Design pressure	300 psig
Design temperature	200° F
Filter element material	Polypropylene
Vessel material	Stainless steel
Seal Water Injection Filter	
Number of units	2
Type	Vertical cylinder cartridge [80gpm type]
Design pressure	3,185 psig
Design temperature	200° F
Filter element material	Polypropylene
Vessel material	Stainless steel
Mixed Bed Demineralizer Inlet Filter	
Number of units	3
Type	Vertical cylinder cartridge [250gpm type]
Design pressure	300 psig
Design temperature	150° F
Filter element material	Polypropylene
Vessel material	Stainless steel

Table 6-3 Chemical and Volume Control System Equipment Design Parameters (Sheet 6 of 6)

Boric Acid Filter	
Number of units	1
Type	Vertical cylinder cartridge [250gpm type]
Design pressure	200 psig
Design temperature	200° F
Filter element material	Polypropylene
Vessel material	Stainless steel
B.A. Evaporator Feed Demineralizer Filter	
Number of units	1
Type	Vertical cylinder cartridge [150gpm type]
Design pressure	200 psig
Design temperature	200° F
Filter element material	Polypropylene
Vessel material	Stainless steel

Table 6-4 Components Cooled by CCWS (Sheet 1 of 2)

Loop	Component	System	Reference
A	A-Containment spray/residual heat exchanger	CS/RHRS	5.4.7
	A-Containment spray/residual heat removal pump	CS/RHRS	5.4.7
	A- Safety injection pump	SIS	6.3
	A- Component cooling water pump	CCWS	9.2.2
B	B-Containment spray/residual heat exchanger	CS/RHRS	5.4.7
	B-Containment spray/residual heat removal pump	CS/RHRS	5.4.7
	B- Safety injection pump	SIS	6.3
	B- Component cooling water pump	CCWS	9.2.2
C	C-Containment spray/residual heat exchanger	CS/RHRS	5.4.7
	C-Containment spray/residual heat removal pump	CS/RHRS	5.4.7
	C- Safety injection pump	SIS	6.3
	C- Component cooling water pump	CCWS	9.2.2
D	D-Containment spray/residual heat exchanger	CS/RHRS	5.4.7
	D-Containment spray/residual heat removal pump	CS/RHRS	5.4.7
	D- Safety injection pump	SIS	6.3
	D- Component cooling water pump	CCWS	9.2.2

Table 6-4 Components Cooled by CCWS (Sheet 2 of 2)

Loop	Component	System	Reference
A1	A- Spent fuel pit heat exchanger	SFPCS	9.1.3
	A- Charging pump	CVCS	9.3.4
	A- Sample heat exchanger	PSS	9.3.2
	A,B- Reactor coolant pump	RCS	5.4.1
C1	B- Spent fuel pit heat exchanger	SFPCS	9.1.3
	B- Charging pump	CVCS	9.3.4
	B- Sample heat exchanger	PSS	9.3.2
	C/V atmosphere gas sample cooler	PSS	9.3.2
	C,D- Reactor coolant pump	RCS	5.4.1
A2	A- Instrument air system	IAS	9.3.1
	Seal water heat exchanger	CVCS	9.3.4
	Excess letdown heat exchanger	CVCS	9.3.4
	A,B,C,D-Blowdown sample cooler	SGBDS	10.4.8
	Auxiliary steam drain monitor heat exchanger	ASSS	10.4.11
	B.A. evaporator	CVCS	9.3.4
	Chemical drain tank pump	LWMS	11.2
	A,B-Waste gas compressor	GWMS	11.3
	Waste gas dryer	GWMS	11.3
C2	B- Instrument air system	IAS	9.3.1
	Letdown heat exchanger	CVCS	9.3.4

Table 6-5 Component Cooling Water System Component Design Data

Component Cooling Water Pump		
Quantity	4	
Type	horizontal centrifugal	
Design flow rate	12,000 gpm	
Design head	180 ft	
Design pressure	200 psig	
Design temperature	200 ^{0}F	
Component Cooling Water Heat Exchanger		
Quantity	4	
Type	Plate type	
Plate Material	Ti	
Heat transfer rate	50.0x 10^6 Btu/hr	
	CCW side	ESW side
Design flow rate	11,000 gpm	11,000 gpm
Design pressure	200 psig	150 psig
Design Temperature	200 ^{0}F	140 ^{0}F
Design Inlet temperature	-	95 ^{0}F
Design outlet temperature	100 ^{0}F	-
Component Cooling Water Surge Tank		
Quantity	2	
Type	Horizontal	
Capacity	283 ft ^{3}	
Design pressure	50 psig	
Design temperature	200 ^{0}F	

Table 6-6 Essential Service Water System Component Design Data

Essential Service Water Pump	
Quantity	4
Type	Vertical, centrifugal, mixed flow
Design flow rate	13,000 gpm
Design pressure	150 psig
Design temperature	140 $^{\circ}$ F
Materials	Stainless steel
Equipment Class	3
Electric Power Supply Class	Class 1E power source
Essential Service Water Pump Outlet Strainer	
Quantity	8
Design flow rate	13,000 gpm
Design pressure	150 psig
Design temperature	140 $^{\circ}$ F
Maximum allowed differential pressure	7 psi at 13,000 gpm
Strainer mesh size	3 mm
Equipment Class	3
Electric Power Supply Class	Class 1E power source
Essential Service Water Pump Discharge Valve	
Quantity	4
Design flow rate	13,000 gpm
Design pressure	150 psig
Design temperature	140 $^{\circ}$ F
Equipment Class	3
Electric Power Supply Class	Class 1E power source

Table 6-7 Spent FuelPit Cooling and Purification System Component Design Parameters (Sheet 1 of 2)

SFP Pumps	
Type	Horizontal centrifugal
Quantity	2
Design pressure	200 psig
Design temperature	200 °F
Normal operating temperature	120 °F
Design flow rate	3,865 gpm
Design pump head	250 feet
Fluid	Boric acid water (4000 ppm)
Material	Stainless steel

SFP Heat Exchangers		
Quantity	2	
Type	Plate type	
Heat transfer rate	28×10^6 BTU/h (per unit)	
	SFP water side	CCWS side
Design flow rate	3,600 gpm	3,600 gpm
Design pressure	200 psig	200 psig
Design temperature	200 °F	200 °F
Inlet temperature	120 °F	100 °F
Fluid	Borated water	Component Cooling Water
Material	Stainless steel	Stainless steel

SFP Demineralizers	
Quantity	2
Type	Vertical cylindrical type
Design pressure	200 psig
Design temperature	200° F
Fluid	Boric acid water (4000 ppm)
Design flow rate	265 gpm
Vessel material	Stainless steel

SFP Filters	
Quantity	2
Type	Vertical cylindrical cartridge type
Design flow rate	265 gpm
Design pressure	200 psig
Design temperature	200 °F
Fluid	Boric acid water (4000 ppm)
Filter element material	Polypropylene
Vessel material	Stainless steel

Table 6-7 Spent Fuel Pit Cooling and Purification System Component Design Parameters (Sheet 2 of 2)

SFP Strainers (at SFP pump intake)	
Number	2
Type	Cylinder type
Design flow rate	3,865 gpm
Normal operating temperature	120 °F
Design pressure	Atmosphere
Design temperature	200° F
Vessel material	Stainless steel
SFP Strainers (at RHR pump intake)	
Number	2
Type	Cylinder type
Design flow rate	3000 gpm
Operating temperature	120 °F
Design pressure	Atmosphere
Design temperature	200 °F
Vessel material	Stainless steel

Table 6-8 Spent Fuel Pit Design Parameters

SFP storage capacity	900 spent fuel assemblies
SFP water volume (below normal water level)	400,000 gal
Boron concentration of water (ppm)	4000